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SWERR-TR-72-74

DEVELOPMENT OF WEAR-RESISTANT ELASTOMERS FOR TRACK PADS

U.S. ARMY WEAPONS COMMAND

TECHNICAL REPORT

Edward W. Bergstrom

October 1972

RESEARCH DIRECTORATE
WEAPONS LABORATORY, WECOM
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ABSTRACT

Correlation between service test wear ratings and laboratory test data obtained at room temperature for tear strength, resistance to crack growth, and abrasion resistance, as previously reported by the Research Directorate of this Command, has been confirmed in the most recent service test conducted at ATAC and Yuma. Of even more importance was the finding that the results of tear tests and crack growth tests conducted at 250°F correlated with service test wear ratings. Track pads prepared from HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750, and Ameripol 1834/Ameripol CB1352 have exhibited up to 56 per cent improvement in tread wear resistance when compared with commercial SBR control pads. On the basis of these results, pads prepared from these experimental compounds should have an average service life of 3000 to 3500 miles. This is an important step toward the ultimate goal of a 5000 mile track pad.

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OBJECTIVE

The object of this work, conducted by personnel of the Research Directorate, Weapons Laboratory, WECOM, was (1) to determine if existing laboratory tests for rubber, or modification of such tests, could be used for predicting the wear resistance of rubber track-pads, and (2) to develop rubber compounds for use in the fabrication of track pads with improved wear resistance.

BACKGROUND

The operating life of track pads used on various armored vehicles such as the M48 and M60 tank series averages only 2200 miles because of the limitations of both the rubber and the metal components. The life of the T142 track, developed to replace the T97E2 track, is limited because, while the metal track remains operational for 5000 miles or more, the average life of the rubber pads is only 1200 to 2600 miles. Past efforts[1-8] have centered on (1) the development of pads that would match the operational life of the track itself, and (2) the development of a laboratory test, or series of laboratory tests, which could be used in predicting the wear resistance of experimental track pad compounds without costly and time-consuming service tests. Much progress has been made toward both these goals. In this report, work done toward meeting both objectives, since issuance of the previous report[8], is covered.

APPROACH

Service tests of the experimental T142 track pads were arranged through the U. S. Army Tank-Automotive Command(ATAC), Warren, Michigan, and were conducted at ATAC and at the Yuma Proving Ground, Yuma, Arizona.

The following wear rating was used to compare the performance of the rubber track pads tested:

$$\text{Volume Wear Rating} = \frac{\text{Average volume loss of commercial SBR control pads}}{\text{Average volume loss of experimental pads}} \times 100$$

A Number 1 Banbury mixer was used to mix all compounds. The Banbury-mixed compound was transferred to a 30-inch mill for additional mixing and sheeting-out. The cooled stock was later transferred to an 18-inch mill for warmup and for sheeting-out to the desired thickness for the preparation of track pad preforms from rolled stock.

The following surface preparations were made on the track pad metal backup plates (inserts) and on the ASTM D429-68 steel test panels prior to vulcanization-bonding to the rubber stocks: degreasing, glass beadblasting, solvent wiping, brush application of bonding agent, and drying.

Static exposure tests of T130 track pads in Panama were arranged through the cooperation of Dr. Leonard Teitell of the Pitman-Dunn Research Laboratories, Frankford Arsenal.

Tensile strength, elongation, and modulus were determined at ambient and elevated temperatures by use of a Scott Model L-6 rubber tensile tester equipped with a Scott Model HTO hot tensile oven and autographic recorder-controller. Each tensile specimen was placed in the grips of the tester and conditioned for six minutes at the elevated temperature before tested. All other physical properties were determined by ASTM procedures where applicable.

Compound formulations together with physical properties (tensile strength, elongation at ambient and 400°F., Shore A Hardness, and tear strength) are given in Table I.

RESULTS AND DISCUSSION

The service test on experimental T142 track pads, prepared by personnel of the Research Directorate at this Command and originally scheduled for late summer 1971, were delayed at ATAC until January 1972. The first part of the projected 2000-mile test was conducted for 750-miles on a paved asphalt test track with an M60A1E2 tank (test weight 98,100 lb.) running at a speed of 30±2 mph. The results of this test are shown in Table II. Results were determined separately for pads positioned on the inside of the metal track and those positioned on the outside of the track. This was done because pads mounted on the outside of the track are subjected to more wear on turns than those on the inside; wear on the outside pads would be primarily due to chunking and tearing. Pads mounted on the inside of the track become worn chiefly because of abrasion. These results show that compounds based on Stereon 750, HYTRANS 1227-289-1, HYTRANS 1227-289-2, Philprene 1609/cis-4 1350, ECD 729/Nordel 1320, Ameripol SN600/Ameripol CB441, and Ameripol 1834/Ameripol CB1352 exhibited significant improvement in resistance to tread wear when compared with the Goodyear commercial control compound. Fiberglas rubber impregnated chopped continuous-strand (RICS) treatment 065, Type A, 1-inch, furnished by Owens-Corning Fiberglas Corporation, was evaluated in selected compounds to determine its effect in improving wear resistance. Results in Table II show that all track pads containing RICS had poorer

TABLE I

COMPOUND FORMULATIONS AND PHYSICAL PROPERTIES

Compounding Ingredients	S152-1	S152-148	S223-4	S223-6	B33-4	S212-2	S212-3	S227-2	B34	B35	E50
	Compound Formulations (Parts by Weight)										
SBR 1500	100	100									
HYTRANS 1227-289-1			137.5	137.5							
HYTRANS 1227-289-2					137.5						
Philprene 1609						101.5	101.5				
Cis-4 1350						64.5	64.5				
Stereon 750								137.5			
Ameripol SN 600									50		
Ameripol CB 441									68.75		
Ameripol 1834										82.5	
Ameripol CB 1352										106.5	
EPCAR 346											80
EPCAR 5465											40
N220 Black									60		
N110 Black											60
Statex 160	45	45	70	70	70			70			
Zinc Oxide	4	4	4	4	4	3	3	2	4	3	5
Stearic Acid	2	2	2	2	2	2	2	2	3.5	2	1
Santocure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4			
Sulfur	2	2	2	2	2	2	2	1.7	1.9	1.8	1
TMTD											0.4
OBTS									1.2	1.1	1
Agerite Resin D									0.75	0.75	
Neozone D	1	1	1	1	1			1			
Sunthene 4240											10
Piccopale 100						3.5	3.5				
Santogard PVI									0.8	0.8	
Thermoflex A						1	1				
Santoflex AW						1.5	1.5				
Santoflex 36									1.25	1.25	
U.O.P. 88	3	3	5	5	5	3	3	5			
Atlantic 1115 Wax									1.5	1.5	
Heliozone	1	1	1	1	1	1	1	1			
Rubber Impregnated Chopped Strand (RICS)		3		3			3				
Cure (minutes @Temp., °F)											
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	35@310	35@310	20@320
T142 Track Pads	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	60@320
				PHYSICAL PROPERTIES							
Tensile Strength, psi, ambient	4140	3880	3240	2840	2805	3220	2880	3000	2725	2750	2940
400°F	420	455	535	550	560	480	435	545	390	510	580
Ultimate Elong., %, ambient	480	460	740	670	630	700	630	800	520	610	530
400°F	150	140	400	300	390	310	280	590	380	370	180
Hardness, Shore A	65	70	59	63	59	59	62	59	60	56	65
Tear, Die C, pi	215	260	205	235	225	245	270	230	225	200	200

TABLE I (Continued)

Compounding Ingredients	53846-1	53846-1GR	53846-2	53846-3	53846-4	53846-5	I65	U65	U68	U68-2
	Compound Formulations (Parts by Weight)									
Neoprene TW	100	100								
Neoprene W			100							
ECD 729				90						
Nordel 1320				10						
ECD 2677					75	100				
Nordel 1700					25					
Hypalon 45					15	15				
Chlorobutyl HT-1066							100			
Vibrathane 5004								Vibrathane 5004 compound received from Uniroyal fully compounded.		
Genthane SR									100	100
ISAF Black	50	50	50	100	100	100				
Kosmobile 77							65			
Statex 160									40	40
Zinc Oxide	5	5	5	5	5	5	5			
Stearic Acid	1	1	2	1	1	1	1		0.2	0.2
Magelite D	4	4	4				1			
Sulfur				1.5	0.5	0.5	0.5			
DiCup 40C									7	7
MBT				0.75	3	3				
CONAC S	0.75	0.75								
NA-101	1	1								
Dodecyl Mercaptan			1							
NA-22			0.75							
Thiuram M			0.75		0.8	0.8				
Methyl Tuads							1			
Thionex				1.5						
Altax							1			
Butyl Zimate					1.5	1.5				
Sulfasan R					0.8	0.8				
Sundex 790	30	30	10							
Sunpar 2280				65	65					
Sunpar 150						75				
Aranox	1	1	1							
Octamine	4	4	4							
Neozone D							1			
Akroflex CD			2							
Polycarbodiimide (PCD)									4	4
Calcium Oxide										5
Rubber Impregnated Chopped Strand (RICS)		5.9								
Cure (minutes @Temp., °F)										
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	40@307	45@310	45@310	45@310
T142 Track Pads	90@307	90@307	150@292	75@320	75@320	75@320	75@320	75@320	75@320	75@320
PHYSICAL PROPERTIES										
Tensile Strength, psi, ambient	2725	2050	3455	2845	2740	2400	2670	4380	4310	4530
400°F	520	490	720	475	650	425	300	610	480	610
Ultimate Elong., %, ambient	380	320	370	460	440	450	480	290	540	450
400°F	180	160	210	280	230	200	200	110	440	340
Hardness, Shore A	64	69	68	64	66	67	65	78	71	73
Tear, Die C, pi	170	160	185	190	196	160	195	152	225	205

TABLE II

RESULTS OF 750 MILE T142 TRACK PAD TEST
AT ATAC (WARREN, MICHIGAN) ON PAVED TRACK

Compound	Description	No. of Pads	Volume Wear Rating: 750 Miles Outside	Volume Wear Rating: 750 Miles Inside	Volume Wear Rating: 750 Miles Combined Outside and Inside
S152-1	Research Directorate Control Compound (SBR 1500)	8	80	128	96
S152-148	Research Directorate Control Compound plus 3 parts/100 rhc rubber impregnated chopped strand (RICS)	8	84	104	92
S223-4	HYTRANS 1227-289-1	8	156	144	149
S223-6	HYTRANS 1227-289-1 (contains 3 parts/100 rhc RICS)	8	131	122	127
B33-4	HYTRANS 1227-289-2	8	162	147	154
S212-2	Philprene 1609/Cis-4 1350	8	144	146	145
S212-3	Philprene 1609/Cis-4 1350 (contains 3 parts/100 rhc RICS)	8	116	128	122
S227-2	Stereon 750	8	163	154	155
53846-1	Neoprene TW	7	*	91	-
53846-1GR	Neoprene TW (contains 5.9 parts/100 rhc RICS)	8	*	57	-

*Excessive chunking after 500 miles; replaced by commercial control compound.

TABLE II (Continued)

Compound	Description	No. of Pads	Volume Wear Rating: 750 Miles Outside	750 Miles Inside	750 Miles Combined Outside and Inside
53846-2	Neoprene W	7	Bond Failures	Bond Failures	-
53846-3	ECD 729/Nordel 1320	8	139	138	138
53846-4	ECD 2677/Nordel 1700	8	Bond Failures	Bond Failures	-
53846-5	ECD 2677	8	Bond Failures	Bond Failures	-
53846-5	ECD 2677 (Two steel plates cured within each pad)	8	Plates caused chunking	Plates caused chunking	-
B34	Ameripol SN 600/Ameripol CB 441	8	148	151	151
B35	Ameripol 1834/Ameripol CB 1352	8	133	149	143
E50	EPCAR 346/EPCAR 5465	8	98	114	106
-	Goodyear Commercial Control	Unknown	100	100	100
S227-2	Stereon 750 - Prepared by Firestone Tire and Rubber Co. on production basis in pilot lot quantity using Research Directorate formulation.	26	159	149	154

wear resistance than pads prepared from the same compounds without the RICS. Also, T142 pads were included in this test. These pads had been fabricated by Firestone Tire and Rubber Co. in pilot lot quantity by use of standard shop production techniques from the Research Directorate's S227-2 formulation. The wear resistance of the Firestone pads was almost identical to that of the pads prepared in the laboratory by the Research Directorate.

Upon completion of the ATAC portion of the test, all track pads which showed signifcantly improved wear resistance, as well as the Goodyear control pads, were removed from the vehicle and forwarded to Yuma Proving Ground, Yuma, Arizona, for the 500-mile gravel and the 750-mile cross-country service tests. Results of the 500-mile test on the gravel track at Yuma are given in Table III; these results show that track pads based on HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750 and Ameripol 1834/Ameripol CB1352 exhibited significant improvement in tread wear compared with the Goodyear controls. Pads based on HYTRANS 1227-289-2, ECD 729/Nordel 1320 and Ameripol SN600/Ameripol CB441 did not hold up as well on the gravel track at Yuma as they did on the asphalt track at ATAC.

Cumulative volume wear ratings after 1250 miles of service testing (750 miles on paved track at ATAC plus 500 miles on gravel at Yuma) for the experimental T142 pads are given in Table IV. Pads based on HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750, and Ameripol 1834/Ameripol CB1352 revealed outstanding improvement in resistance to tread wear when compared with the commercial control. Pads based on HYTRANS 1227-289-2 and Ameripol SN600/CB441 also showed significant improvement in wear resistance, but this improvement was not of the magnitude of that for those pads mentioned previously. Pads based on ECD 729/Nordel 1320 showed poorer resistance to tread wear than the commercial control.

Upon completion of the gravel test, pads based on compounds S152-1, S152-148, S223-6, B33-4, 53846-3, and B34 were removed from the test vehicle even though pads of compounds S223-6, B33-4, and B34 exhibited significantly improved wear resistance over the commercial control. The judgment of the personnel conducting the test at Yuma was that pads based on the above-cited compounds would perform less well during the 750-mile cross-country test. Likewise, 12 of the 20 Goodyear commercial control pads had to be removed from the test vehicle because of excessive wear. Thus, all pads based on compounds S223-4, S227-2, S212-2, S212-3, and B35, and 8 Goodyear control pads remained on the vehicle for the 750-mile level cross-country test. Upon completion of this test,

TABLE III

RESULTS OF 500 MILE T142 TRACK PAD TEST AT YUMA PROVING GROUND ON GRAVEL TRACK

Compound	Description	Volume Wear Rating 0-250 Miles	250-500 Miles	500 Miles Cumulative
S152-1	Research Directorate Control Compound (SBR 1500)	79	98	86
S152-148	Research Directorate Control Compound plus 3 parts/100 rhc R1CS	108	99	104
S223-4	HYTRANS 1227-289-1	232	134	179
S223-6	HYTRANS 1227-289-1 (Contains 3 parts/100 rhc R1CS)	212	99	146
B33-4	HYTRANS 1227-289-2	185	74	114
S212-2	Philprene 1609/cis-4 1350	215	175	196
S212-3	Philprene 1609/cis-4 1350 (Contains 3 parts/100 rhc R1CS)	197	146	172
S227-2	Stereon 750	322	149	218
53846-3	ECD 729/Nordel 1320	77	45	60
B34	Ameripol SN600/Ameripol CB441	115	111	113
B35	Ameripol 1834/Ameripol CB1352	174	166	171
----	Goodyear Commercial Control	100	100	100

TABLE IV

VOLUME WEAR RATING OF T142 PADS AFTER 1250-MILES OF SERVICE TESTING
(750-MILES ON PAVED TRACK AT ATAC PLUS 500-MILES ON GRAVEL AT YUMA)

Compound	Description	Cumulative Volume Wear Rating 1250 Miles (ATAC Plus Yuma)
S152-1	Research Directorate Control Compound (SBR 1500)	90
S152-148	Research Directorate Control Compound plus 3 parts/100 rhc RICS	102
S223-4	HYTRANS 1227-289-1	173
S223-6	HYTRANS 1227-289-1 (contains 3 parts/100 rhc RICS)	143
B33-4	HYTRANS 1227-289-2	126
S212-2	Philprene 1609/cis-4 1350	179
S212-3	Philprene 1609/cis-4 1350 (contains 3 parts/100 rhc RICS)	153
S227-2	Stereon 750	199
53846-3	ECD 729/Nordel 1320	73
B34	Ameripol SN600/Ameripol CB441	125
B35	Ameripol 1834/Ameripol CB1352	165
-	Goodyear Commercial Control	100

cumulative wear ratings were determined on the pads which had been tested for the entire 2000 miles. These values are given in Table V and show that pads based on HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750, and Ameripol 1834/ Ameripol CB1352 exhibited significant improvement in tread wear when compared with the Goodyear control. On the basis of these results, rubber track pads prepared from these experimental compounds should have an average service life of 3000 to 3500 miles. This is an important step toward the ultimate goal of a 5000-mile pad.

For improvement of wear resistance of track pads, various flex-cracking inhibitors were evaluated in selected compounds. These results are shown in Table VI. All inhibitors were incorporated at concentrations normally needed to provide ozone protection in accelerated ozone tests (50±5 pphm ozone at 100±2°F-bent loop specimen) since many of the compounds recommended as effective flex-cracking inhibitors are also effective antiozonants; furthermore, an effective antiozonant also proved to be an effective flex-cracking inhibitor would be noteworthy. The antiozonant used in all experimental T142 track pads prepared from these compounds was U.O.P. 88. The results show that a 50/50 U.O.P. 88/Santoflex AW combination (also an effective antiozonant combination) was the most effective in the Research Directorate control compound (S152-1) and also one of the most effective in the Stereon 750 (S227-2) and HYTRANS (B33-4) compounds. (Santoflex AW was most effective alone in the Stereon S227-2 and HYTRANS compounds, however, this is not an effective antiozonant when used alone and would have to be used in conjunction with an antiozonant such as U.O.P. 88). In the Philprene 1609/cis-4 1350 compound, U.O.P. 88, which is now used in this compound to provide ozone resistance, also proved to be one of the most effective flex cracking inhibitors along with Eastozone 33 and the 50/50 U.O.P. 88/Santoflex AW combination.

Plasticizers or softeners are often used in rubber compounds to achieve one or a combination of the following purposes:

(1) reduce mixing and processing temperature.

(2) aid in incorporating and dispersing dry ingredients.

(3) modify the physical properties of the vulcanizates.

(4) aid in processing the uncured stock by reduction of the nerve or softening of the mixture.

TABLE V

VOLUME WEAR RATING OF T142 PADS AFTER 2000-MILES OF SERVICE TESTING (750 MILES PAVED TRACK AT ATAC PLUS 500 MILES ON GRAVEL AND 750 MILES LEVEL CROSS COUNTRY AT YUMA)

Compound	Description	Cumulative Volume Wear Rating 2000 Miles (ATAC plus Yuma)
S223-4	HYTRANS 1227-289-1	135
S212-2	Philprene 1609/cis-4 1350	152
S212-3	Philprene 1609/cis-4 1350 (contains 3 parts/100 rhc RICS)	143
S227-2	Stereon 750	156
B35	Ameripol 1834/Ameripol CB1352	141
-	Goodyear Commercial Control	100

TABLE VI

EVALUATION OF FLEX-CRACKING AGENTS
IN VARIOUS TRACK PAD COMPOUNDS

Crack Growth, DeMattia Tester, 32nds of an inch

S152-1 (SBR1500 Control Compound)

No. of Cycles Flexed	Control (No Inhibitor)	Santo-flex AW	U.O.P. 88	50/50 U.O.P.88/ Santo-flex AW	Antioxi-dant 4010	Easto-zone 33	U.O.P. 688	Agerite Super Flex
10,000	15	10	11	8	10	8	14	12
20,000	21	16	17	13	17	16	20	20
30,000	26	20	22	16	21	20	23	25
40,000	cracked across	23	25	18	25	24	27	29
50,000	-	25	30	22	cracked across	26	cracked across	cracked across

(all inhibitors evaluated at concentration of 3 parts/100 rhc)

TABLE VI (continued)

S227-2 (Stereon 750)

No. of Cycles Flexed	Control (No Inhibitor)	Santo-flex AW	U.O.P. 88	50/50 U.O.P.88/ Santo-flex AW	Antioxi-dant 4010	Easto-zone 33	U.O.P. 688	Agerite Super Flex
10,000	14	2	5	2	6	4	6	9
20,000	22	6	12	6	13	9	12	17
30,000	24	10	15	11	16	13	14	19
40,000	26	13	18	13	19	17	18	23
50,000	27	15	21	17	22	21	20	26

(all inhibitors evaluated at concentration of 5 parts/100 rhc)

B33-4 (HYTRANS 1227-289-2)

No. of Cycles Flexed	Control (No Inhibitor)	Santo-flex AW	U.O.P. 88	50/50 U.O.P.88/ Santo-flex AW	Antioxi-dant 4010	Easto-zone 33	U.O.P. 688	Agerite Super Flex
10,000	12	3	12	8	11	12	10	12
20,000	19	5	19	10	18	16	14	19
30,000	22	7	23	13	24	19	18	23
40,000	-	9	-	14	-	21	20	-
50,000	26	10	27	17	27	22	24	28

(all inhibitors evaluated at concentration of 5 parts/100 rhc)

TABLE VI (continued)

S212-2 (Philprene 1609/cis-4 1350 Blend

No. of Cycles Flexed	Control (No Inhibitor)	Santoflex AW	U.O.P. 88	50/50 U.O.P.88/ Santoflex AW	Antioxidant 4010	Eastozone 33	U.O.P. 688	Agerite Super Flex
10,000	6	2	2	2	5	2	5	5
20,000	11	6	5	6	9	4	10	9
30,000	14	10	7	8	12	7	12	13
40,000	17	12	8	10	15	8	14	15
50,000	18	14	10	11	18	10	15	16

(all inhibitors evaluated at concentration of 3 parts/100 rhc)

(5) extend the amount of rubber by substitution of oil for rubber.

(6) improve flexibility and elastic recovery at extremely low temperatures.

For these reasons, naphthenic (Flexon 765), paraffinic (Flexon 875), and aromatic (Flexon 290) plasticizers (all manufactured by Humble Oil and Refining Co.) were evaluated in the Research Directorate SBR 1500 control compound at concentrations of 5, 10, 15, 20, and 25 parts/100 rhc to determine their effect on various physical properties. These results are shown in Table VII. Resistance to crack growth as measured on the DeMattia Flexometer was the only property significantly improved by the addition of the plasticizers. In general, all other properties were either adversely affected or affected insignificantly, regardless of the type of plasticizer used. On the basis of these results and correlation found between laboratory tests and service tests[8], the addition of any of the above cited plasticizers would not improve the wear resistance of <u>this particular compound</u>. On the other hand, the addition of oils or plasticizers to certain compounds will result in significant resistance to wear. All four of the compounds used in preparing T142 track pads which have shown the most significant improvement in service tests thus far, namely, those based on Stereon 750, HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, and Ameripol 1834/Ameripol CB1352, contain some extending oil. Stereon 750 and HYTRANS 1227-289-1, for example, contain 37.5 parts extending oil. As will be shown later, the same laboratory test data, from which the conclusion was drawn that the addition of plasticizers will not improve wear resistance, show that track pads prepared from the four compounds mentioned above would be improved to significantly resist wear.

In previous work[8], correlation was found to exist between service test wear ratings and laboratory test data for tear strength, resistance to crack growth, and abrasion resistance provided these properties are examined together. Whenever all three properties, for a compound being evaluated, were found superior to those of the Research Directorate SBR control compound, the compound being evaluated had a better wear rating than that of the SBR control, which has wear ratings similar to those of commercial SBR pads in numerous service tests. This correlation was confirmed in the recent service test run at ATAC and Yuma. Correlation of physical properties with wear ratings are given in Table VIII. Note that, when the properties of tear strength, resistance to crack growth, and abrasion resistance of the experimental

TABLE VII

EFFECT OF P[illegible]S[illegible]ZERS ON PHYSICAL PROPERTIES
OF SBR 1500 [illegible]NTROL COMPOUND (S152-1)

Type of Plasticizer	Parts Oil/ 100 rhc	Tear Resistance, Die C Original	Tear Resistance, Die C @250°F	Tear Resistance, Die C @300°F	DeMattia, Crack Size after 50,000 Cycles, 32nds of an inch	Abrasion, Vol. Loss, c.c.	(% of Ref. Cpd.)	Heat Buildup, Time to go from 100-200°F	Specific Gravity	Original Tensile, psi	Hardness, Shore A	High Temp. Prop. Tensile @300°F	High Temp. Prop. Elongation @300°F
Naphthenic	0	215	100	90	25	1.174		20 min	1.14	3495	65	860	210
Naphthenic	5	205	95	75	25	1.238	(95%)	18.4 min	1.14	3820	62	800	230
Naphthenic	10	200	90	75	18	1.237	(95%)	18.1 min	1.12	3390	60	540	230
Naphthenic	15	190	100	65	17	1.187	(99%)	16.5 min	1.12	3190	57	620	230
Naphthenic	20	175	80	65	15	1.210	(97%)	16.4 min	1.10	2920	54	465	230
Naphthenic	25	160	65	65	14	1.122	(105%)	13.5 min	1.10	2670	50	425	240
Paraffinic	0	220	120	110	26	1.128		22 min	1.14	3535	66	905	240
Paraffinic	5	215	100	100	22	1.269	(89%)	24 min	1.14	4000	63	800	220
Paraffinic	10	215	80	105	22	1.220	(92%)	20 min	1.13	3900	61	710	240
Paraffinic	15	205	115	100	22	1.250	(90%)	17.8 min	1.12	3900	55	600	270
Paraffinic	20	175	90	85	18	1.189	(95%)	16.5 min	1.11	3530	54	615	290
Paraffinic	25	165	80	90	14	1.212	(93%)	16.[illegible] min	1.10	3265	49	460	290
Aromatic	0	205	110	110	30	1.305		28.5 min	1.14	3910	66	855	230
Aromatic	5	200	120	110	28	1.283	(102%)	26.3 min	1.14	3810	65	800	240
Aromatic	10	205	130	110	22	1.258	(104%)	20.3 min	1.13	3645	61	690	250
Aromatic	15	200	140	115	21	1.180	(111%)	17.5 min	1.13	3850	59	615	260
Aromatic	20	185	130	110	19	1.222	(106%)	16.0 min	1.12	3465	57	525	270
Aromatic	25	185	120	105	15	1.197	(109%)	16.0 min	1.12	3525	54	545	290

TABLE VIII

CORRELATION OF PHYSICAL PROPERTIES
WITH WEAR RATINGS

Compound	Elastomer	Service Test Wear Rating (750 Miles)	Service Test Wear Rating (1250 Miles)	Service Test Wear Rating (2000 Miles)	Tear Strength, pi, Die C		Crack Growth, DeMattia, 32nds of an inch, 50,000 Cycles	Abrasion Resistance, DuPont Abrader, 25 min., Vol.Loss, c.c. (% of Ref. Cpd.)		Tensile Strength Ambient	Hardness, Shore A Ambient
					Ambient	Tested @250°F					
S152-1	Research Directorate Control Compound (SBR 1500)	96	90	-	215	130	Cracked across 50,000 cycles	1.286	(100)	4140	66
S152-148	Research Directorate Control Compound plus 3 parts/100 rhc RICS	92	102	-	260	120	Cracked across 50,000 cycles	1.297	(98)	3880	70
S223-4	HYTRANS 1227-289-1	149	173	135	205	200	14	0.296	(435)	3240	59
S223-6	HYTRANS 1227-289-1 (contains 3 parts/100 rhc RICS)	127	143	-	235	195	16	0.332	(387)	2840	63
B33-4	HYTRANS 1227-289-2	154	126	-	225	160	21	0.120	(1072)	2805	59
S212-2	Philprene 1609/cis-	145	179	152	245	160	14	0.336	(383)	3220	59
S212-3	Philprene 1609/cis-4 1350 (contains 3 parts/100 rhc RICS)	122	153	143	270	150	12	0.287	(448)	2880	62
S227-2	Stereon 750	155	199	156	230	225	19	0.145	(888)	3000	59
53846-1	Neoprene TW	Excessive chunking @500 miles (removed)	-	-	170	70	22	0.386	(349)	2725	64
53846-1 (GR)	Neoprene TW (contains 5.9 parts/100 rhc RICS)	Excessive chunking @500 miles (removed)	-	-	160	70	28	0.898	(143)	2050	69
53846-3	ECD 729/Nordel 1320	138	73	-	190	70	28	1.204	(107)	2845	64
B34	Ameripol SN600/Ameripol CB441	151	125	-	225	220	14	0.088	(1461)	2725	60
B35	Ameripol 1834/Ameripol CB1352	143	200	141	200	200	24	0.113	(1138)	2750	66

compounds are superior to those of the Research Directorate control compound, the wear ratings are also superior. Because several compounds with high wear-ratings showed high retention of tear strength at 250°F (a temperature known to be frequently reached by track pads in service tests), (note compounds S223-4, S227-2, B34, and B35, for example), this is apparently significant.

For further insight into the reasons for the improvement in wear ratings resulting from the use of certain experimental compounds and possible expansion of the laboratory tests valuable in screening experimental compounds for potential use in track pads, crack growth and abrasion resistance were determined at elevated temperatures. These results are shown in Tables IX and X. Results in Table IX show that compounds based on Stereon 750, HYTRANS 1227-289-2, and SBR1609/cis-4 1350 exhibited significantly better resistance to crack growth at 212°F and 250°F than the control. These compounds also showed higher wear ratings in service tests than the control. Whether the measurement of crack growth at elevated temperature would be beneficial as an additional screening test is doubtful at this time because the crack growth resistance of the experimental compounds measured at ambient temperature was initially better than that of the control compound. However, the tests at elevated temperatures seem to indicate, as in the case of the tear resistance measured at 250°F, that significant tread wear improvement in experimental compounds is linked to good retention of certain physical properties at elevated temperatures. Curves representing the resistance to crack growth at elevated temperatures for the Research Directorate control compound in comparison with the experimental Stereon 750 compound are given in Figures 1 and 2.

No correlation was found between resistance to abrasion at 212°F and tread wear ratings in service tests, as shown in Table X, although correlation exists at ambient temperature, as mentioned previously. Because no correlation was found at 212°F, this is believed to be due to the test apparatus used (DuPont abrader). This tester involves a rotating sandpaper disc abrader. At 212°F, the sandpaper becomes clogged with rubber, especially the highly oil extended types, faster than it can be removed by the air blowers; thus a smoother and less abradent surface is being produced as the test progresses. This does not happen at ambient temperature. The assumption is that, if a different abrader, such as the PICO is used, correlation would be found to exist at elevated temperatures.

TABLE IX

RESISTANCE TO CRACK GROWTH OF VULCANIZATES TESTED AT ELEVATED TEMPERATURES

Tested @ Ambient (90°F)

S152-1 (SBR Control - Contains U.O.P. 88)		S152-1 (SBR Control - Contains 50/50 U.O.P. 88/Santoflex AW)		S227-2 (Stereon 750)		B33-4 (HYTRANS 1227-289-2)		S212-2 (SBR 1609/cis-4 1350 Blend)	
No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)
10,000	12	10,000	7	10,000	6	10,000	8	10,000	1
20,000	17	20,000	13	20,000	12	20,000	14	20,000	6
30,000	23	30,000	18	30,000	15	30,000	18	30,000	11
40,000	cracked across	40,000	20	40,000	19	40,000	21	40,000	15
50,000	-	50,000	24	50,000	22	50,000	25	50,000	18

Tested @212°F

S152-1 (SBR Control - Contains U.O.P. 88)		S152-1 (SBR Control - Contains 50/50 U.O.P. 88/Santoflex AW)		S227-2 (Stereon 750)		B33-4 (HYTRANS 1227-289-2)		S212-2 (SBR 1609/cis-4 1350 Blend)	
No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)
10,000	30	10,000	29	4,500	8	4,500	7	4,500	13
11,000	cracked across	11,000	cracked across	10,000	13	9,800	12	9,800	15
				15,000	15	15,500	15	15,500	16
				20,000	18	21,300	17	21,300	18
				28,000	21	31,000	19	31,000	19
				39,000	22	40,000	22	40,000	22
				50,000	24	50,000	26	50,000	24

Tested @250°F

S152-1 (SBR Control - Contains U.O.P. 88)		S152-1 (SBR Control - Contains 50/50 U.O.P. 88/Santoflex AW)		S227-2 (Stereon 750)		B33-4 (HYTRANS 1227-289-2)		S212-2 (SBR 1609/cis-4 1350 Blend)	
No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)	No. of Cycles	Crack Growth (32nds of an inch)
3,000	22	3,000	22	9,800	15	6,800	15	6,800	15
6,600	25	6,300	26	20,800	24	13,100	18	13,100	18
8,000	26	8,000	28	30,500	27	20,100	22	20,100	21
9,800	cracked across	9,100	cracked across	36,000	31	29,700	23	29,700	22
				40,000	cracked across	40,000	24	40,000	24
						50,000	28	50,000	27

TABLE X

RESISTANCE TO ABRASION OF VULCANIZATES TESTED AT ELEVATED TEMPERATURE

		Abrasion Resistance, DuPont Abrader			
		Ambient		212°F	
Compound	Elastomer Type	Volume Loss, cc	% of SBR Reference Compound	Volume Loss, cc	% of SBR Reference Compound
S152-1	SBR 1500 Control Compound	1.3619	-	0.1906	-
S227-2	Stereon 750	0.1464	930	0.2034	93
B33-4	HYTRANS-90/10 Butadiene/Isoprene Type (37.5 parts oil extended)	0.1158	1176	0.2138	89
S212-2	Philprene 1609/cis-4 1350 Blend	0.3275	416	0.1353	140

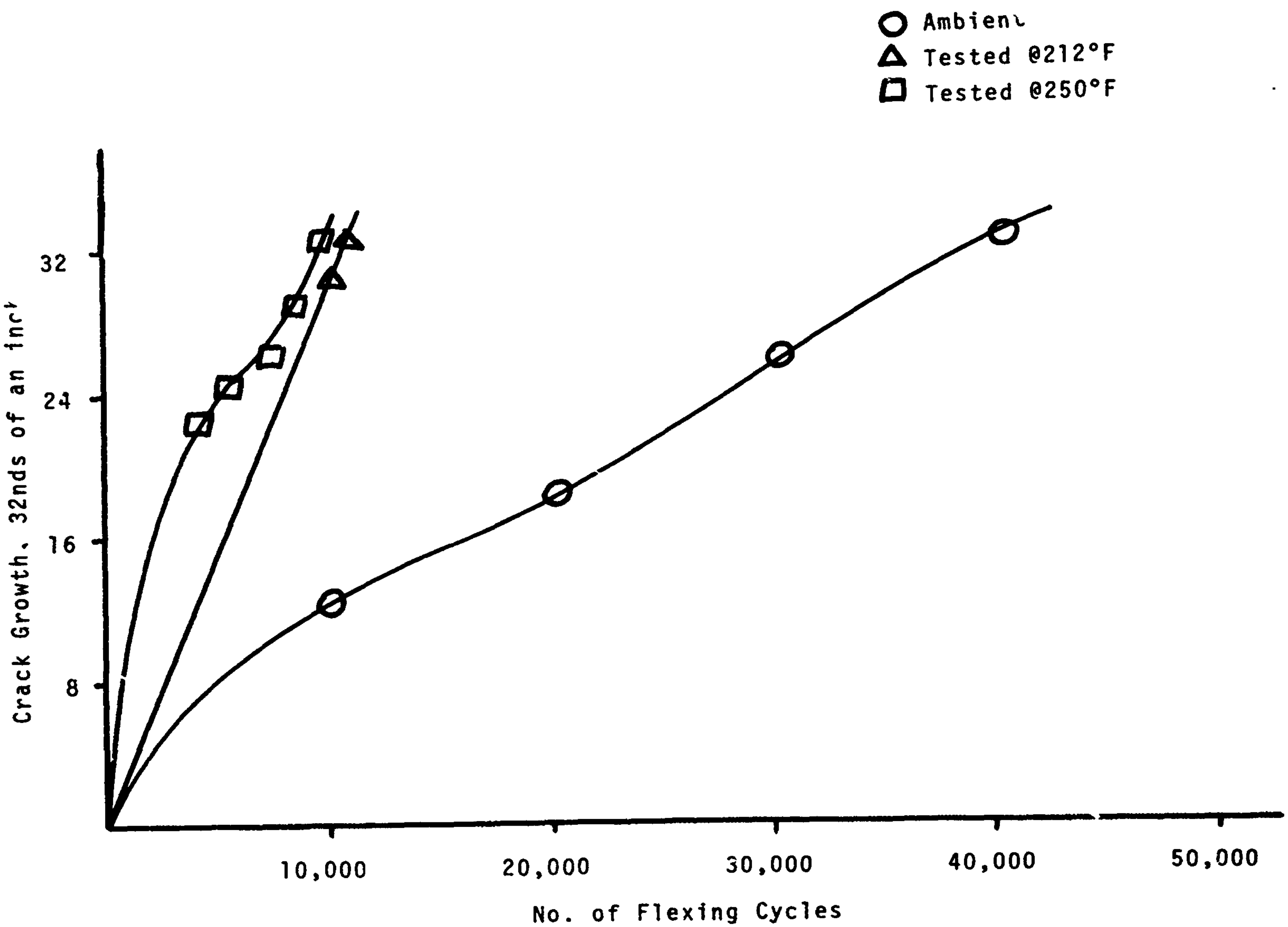

FIGURE 1 RESISTANCE TO CRACK GROWTH AT ELEVATED TEMPERATURES

S152-1 (SBR Research Directorate Control)

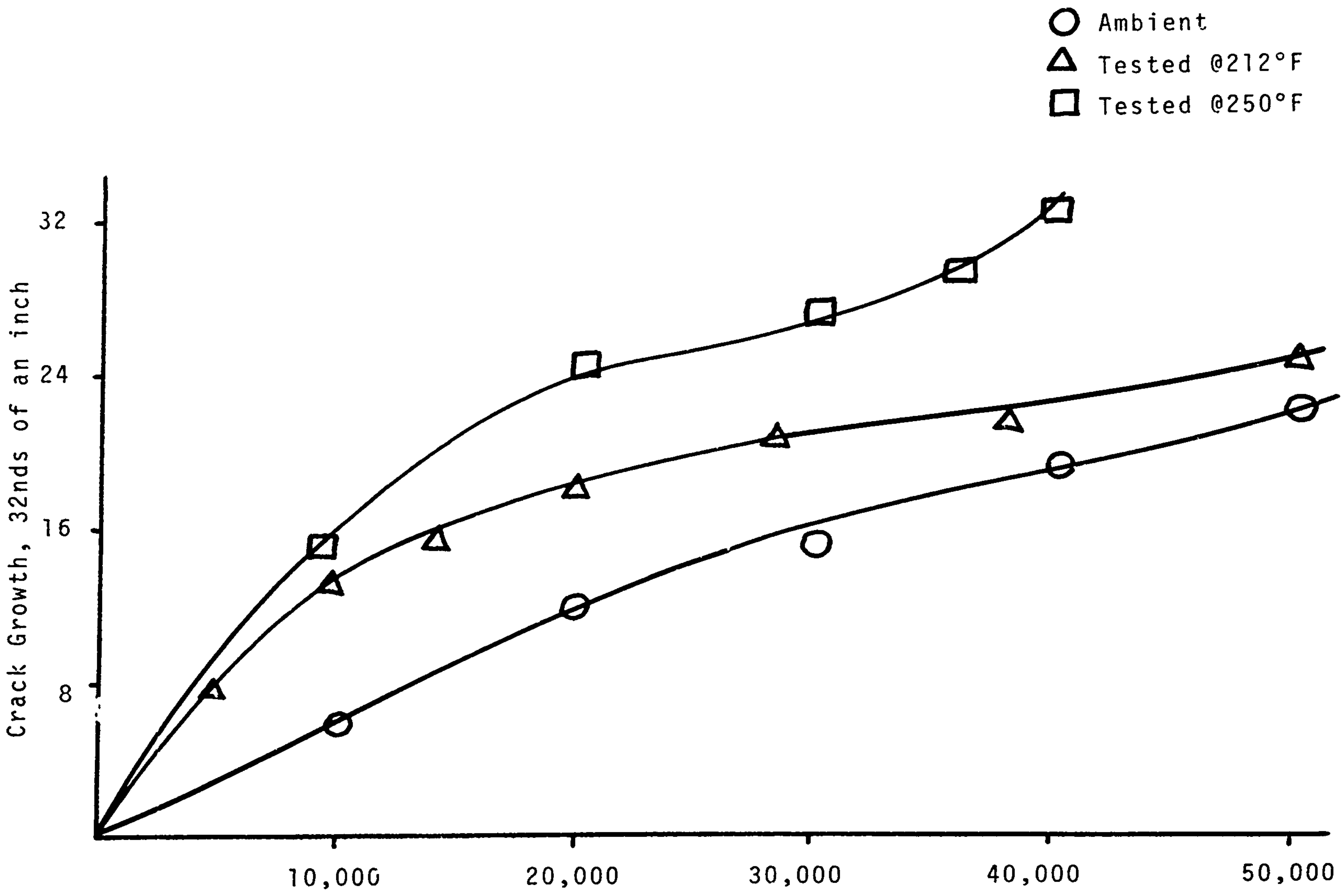

FIGURE 2 RESISTANCE TO CRACK GROWTH AT ELEVATED TEMPERATURES

S227-2 (Stereon 750)

The rubber-to-metal bond strength for various elastomers was determined after specimens were shelf-aged indoors for 36 months. These results are given in Table XI. In some instances, a 90-degree peel strength improved after 36 months' shelf-aging. Results of rubber-to-metal bond strengths after shelf-aging indoors have been previously reported.[6,7]

In previous reports on this subject,[6,7] results were given for T130 track pads prepared from a polyester urethane, Genthane SR, with and without an additive, after outdoor exposure to the open sun and rain forest in Panama. After three years, the pads containing no additive (hydrolysis inhibitor) had deteriorated (soft and tarlike) to such an extent that neither physical properties of the rubber nor rubber-to-metal bond strength of the pads could be determined. Pads of the compound containing 4 parts/100 rhc of a hydrolysis inhibitor (polycarbodiimide-PCD) have now been returned from Panama after five years' exposure. All pads had deteriorated to the same extent after five years' exposure as the pads containing no inhibitor had after three years' exposure. No additional pads remain in test.

CONCLUSIONS

Correlation exists between service test wear ratings and laboratory test data for tear strength, resistance to crack growth, and abrasion resistance. This was reported previously[8] by the Research Directorate at this Command and has been confirmed in the most recent service test at ATAC and Yuma. These laboratory tests will be useful in predicting the service life of pads fabricated from experimental elastomeric compositions, thus the need for costly and time-consuming service tests in the field will be minimized.

Correlation has also been found between (1), the results of tear tests performed at 250°F and results of service tests and (2), results of crack growth tests at 250°F and service test results. Since track pads frequently reach temperatures as high as 250°F during service, the significantly better wear ratings of certain compounds are probably directly related to their high resistance to tear and crack growth at elevated temperatures.

The DuPont Abrader is reliable for measuring abrasion resistance at ambient temperatures, but does not provide accurate data at elevated temperatures.

TABLE XI

RUBBER-TO-METAL BOND STRENGTH OF ELASTOMERS AFTER 36 MONTHS' SHELF-AGING

Compound	Elastomer	Bonding System	Original 90-Degree Peel Strength, pi	Type of Failure*	90-Degree Peel Strength After 36 Months Shelf Aging	Type of Failure*
I65	Chlorobutyl HT-1066	TY-PLY UP/BC	55	BF	47	BF
I65	Chlorobutyl HT-1066	TY-PLY UP/BC (2 coats BC)	130	RF	150	RF
I65	Chlorobutyl HT-1066	Chemlok 205/231	85	B/RF	75	B/RF
I65	Chlorobutyl HT-1066	Chemlok 205/EX-B60-04	35	BF	35	BF
U65	Vibrathane 5004	Chemlok 205/TS-701-45	132	RF	135	RF
U68	Genthane SR w/PCD	Chemlok 205,TS-701-45	145	RF	195	B/RF
U68-2	Genthane SR w/PCD plus CaO	Chemlok 205/TS-701-45	130	RF	145	RF

*BF - Bond Failure

RF - Rubber Failure

B/RF - Part Bond/Part Rubber Failure

Note: One coat each of prime and cover coats were used, except as indicated

T142 track pads prepared from HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750, and Ameripol 1834/Ameripol CB 1352 have exhibited up to 56 per cent improvement in tread wear resistance in recent service tests when these compounds were compared with commercial SBR control pads. On the basis that the average service life of the commercial pads now used averages 2200 miles or less, pads prepared from the four experimental compounds should have an average service life of approximately 3000 to 3500 miles. This is an important step toward the ultimate goal of a 5000-mile track pad.

Certain flex-cracking inhibitors were effective in the compounds tested. A combination of 50/50 U.O.P. 88/Santoflex AW was effective in all the compounds tested. This combination of inhibitors is also an effective antiozonant.

RECOMMENDATIONS

Scale-up to production levels (in pilot lot quantities) should be performed by ATAC on compositions based on HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750 and Ameripol 1834/Ameripol CB 1352. Track pads prepared from these compounds should then be service tested on a test course of various types of terrain (paved, gravel, and cross country) and compared with commercial control track pads, preferably prepared by more than one manufacturer who now supplies them, so that no doubt will exist as to the improvement in tread wear resistance afforded by the experimental compounds.

Additional compounding studies should be performed by the Research Directorate at the Weapons Command on Stereon 750, the HYTRANS elastomers, and SBR/polybutadiene blends to further improve the potential of these compounds in providing track pads with improved tread wear. Any promising new elastomers that become available should also be evaluated by those laboratory tests by which results have been provided that correlate with service test results.

Additional improvement in tread wear of experimental compounds should be attempted, (1) with the use of various reinforcement agents other than or in addition to carbon black, and-or, (2) with the change of "internal" design of the pad through the use of metal plates, screen or wire to reduce the heat buildup which contributes to premature failure of pads.

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13 ABSTRACT

Correlation between service test wear ratings and laboratory test data obtained at room temperature for tear strength, resistance to crack growth, and abrasion resistance, as previously reported by the Research Directorate of this Command, has been confirmed in the most recent service test conducted at ATAC and Yuma. Of even more importance was the finding that the results of tear tests and crack growth tests conducted at 250°F correlated with service test wear ratings. Track pads prepared from HYTRANS 1227-289-1, Philprene 1609/cis-4 1350, Stereon 750, and Ameripol 1834/Ameripol CB1352 have exhibited up to 56 per cent improvement in tread wear resistance when compared with commercial SBR control pads. On the basis of these results, pads prepared from these experimental compounds should have an average service life of 3000 to 3500 miles. This is an important step toward the ultimate goal of a 5000 mile track pad. (U) (Bergstrom, Edward W.)

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2. Tank Track Pads
3. Service Tests
4. Properties - General
5. Wear Resistance
6. Bonding Agents

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